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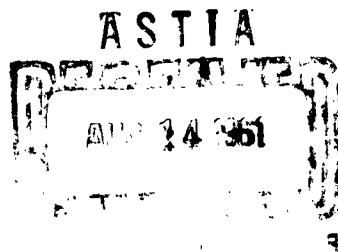
Progress Report No. 39
for the period
July 1, through July 30, 1961

on

EVOLUTION OF ULTRA-HIGH STRENGTH STEELS, AND RESEARCH ON MATERIALS AND VARIOUS NOVEL TECHNIQUES OF FABRICATION OF HIGH PERFORMANCE ROCKET MOTOR CASES

Mellon Institute Project No. 381-3

Submitted to:
Bureau of Naval Weapons
Code SP-271
under
Prime Contract: NOrd 18169



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PROGRESS MADE DURING THE MONTH OF JULY, 1961

A. The mechanical properties of 0.0045 in. diameter beryllium filament have been determined. Data given in Table I indicate that beryllium wire is approximately twice as strong as 6061-T-913 aluminum alloy wire. Although the current price of beryllium wire is around \$2.75 per linear foot, a considerable price reduction can be expected if large quantities of wire has to be manufactured. If a program on beryllium and Be-alloy wire drawing is now initiated, metallic filament wound missile motor case development work can be materially advanced.

Aluminum filament wound and epoxy bonded sphere manufacturing work is now progressing satisfactorily. Two approximately 10 in. diameter spheres will be ready during the third week in August.

At the completion of this task, considerations will be given to wind similar spheres using both aluminum alloy and beryllium wires in the same work piece. Such interweaving is expected to produce a more rigid and stronger sphere.

B. Fatigue studies directed toward showing the effect of various austenitization temperature on the fatigue life and endurance limit have been completed for air melted Rocloy 270. The results seem to indicate that use of austenitization temperatures above and below the optimum temperature lowers the endurance limit and reduces

TABLE I

Results of Tensile Tests^(a) on .0045 in. Diameter Beryllium Wire^(b)

<u>Test Number</u>	<u>0.2% offset Yield Strength ksi</u>	<u>Ultimate Tensile Strength ksi</u>
1	144	177
2	136	179
3	144	178

(a) Test conducted in accordance with ASTM specifications.

(b) As-drawn condition.

the fatigue life. Similar work on vacuum induction melted and vacuum arc remelted Rocloy 270 is in progress. Complete results of this study will be reported in a brochure which is being prepared on Rocloy 270.

C. Analyses of the mechanical properties of MX-2 hydrospun vessel, Serial No.: Unit #2, have been completed. Primary interest was focused on the effect of hydrospinning on the fracture toughness of the parent material and the welded area.

The vessel was fabricated from sheet material measuring 48" x 40" x .150" thick. The sheet was rolled, welded, and hydrospun to its final dimensions of 13.900 in. diameter x 38 in. (spun length) x .060 in. thick in two steps with a spheroidize anneal between hydrospin passes. The final reduction of wall thickness was 60 per cent.

Figure 1 shows the directions and locations from which the tensile specimens and metallurgical samples were taken for a study. The standard unnotched flat tensiles were taken to show the directionality effects, if any, on the heat treated material and also as a check on the strength level attained by the heat treatment.

As received metallurgical samples were first processed and micrographs were made. Figure 2 explains in a pictorial manner the three directions from which the micrographs were taken. Figures 3, 4 and 5 show the above condition. It is readily seen from these figures that the spheroids are elongated in the direction of the roller tool marks.

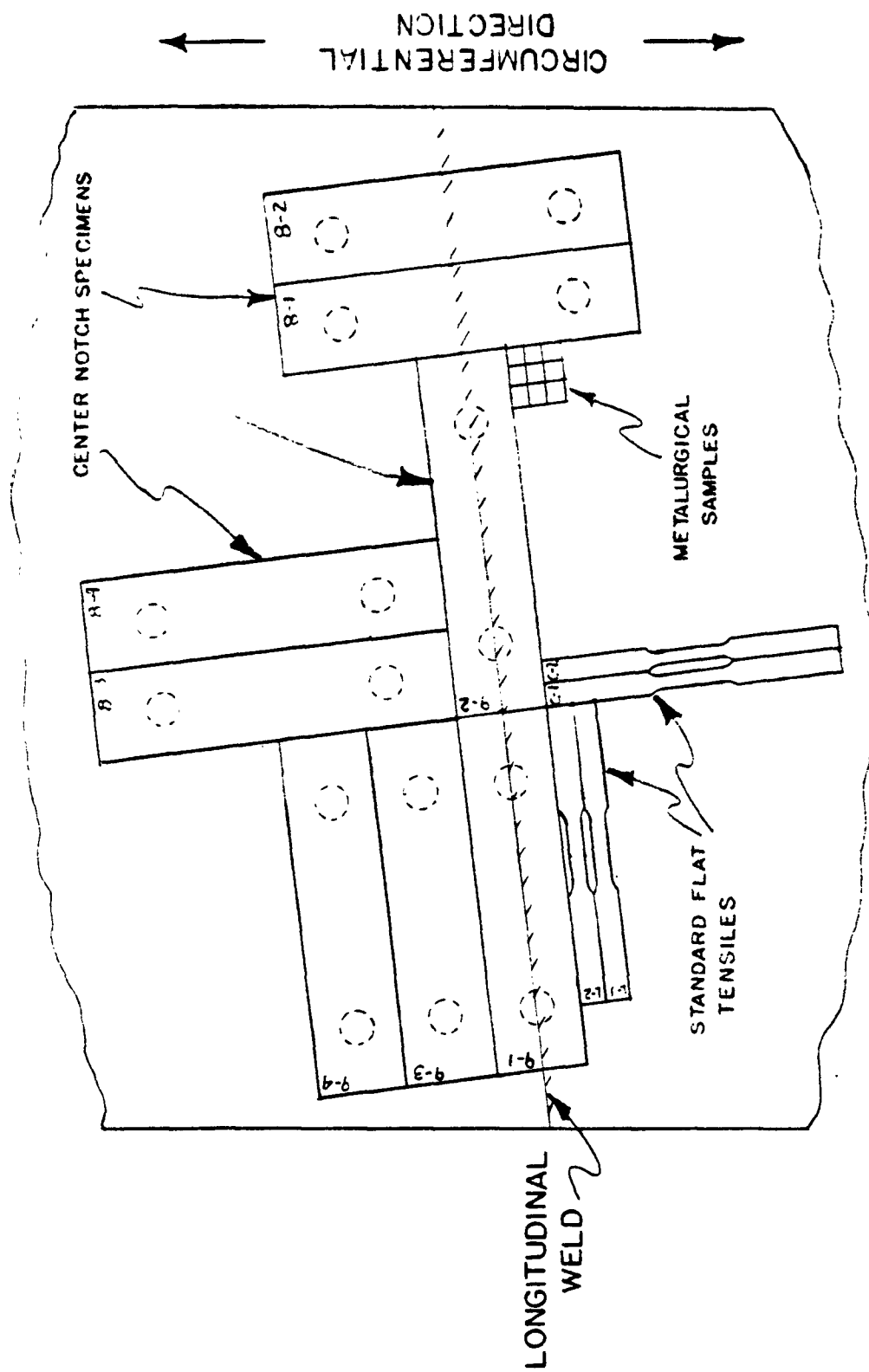


Figure 1
Relative Positions of Test Specimens to the
Longitudinal Weld of the MX-2 Hydrospun Vessel.

5.

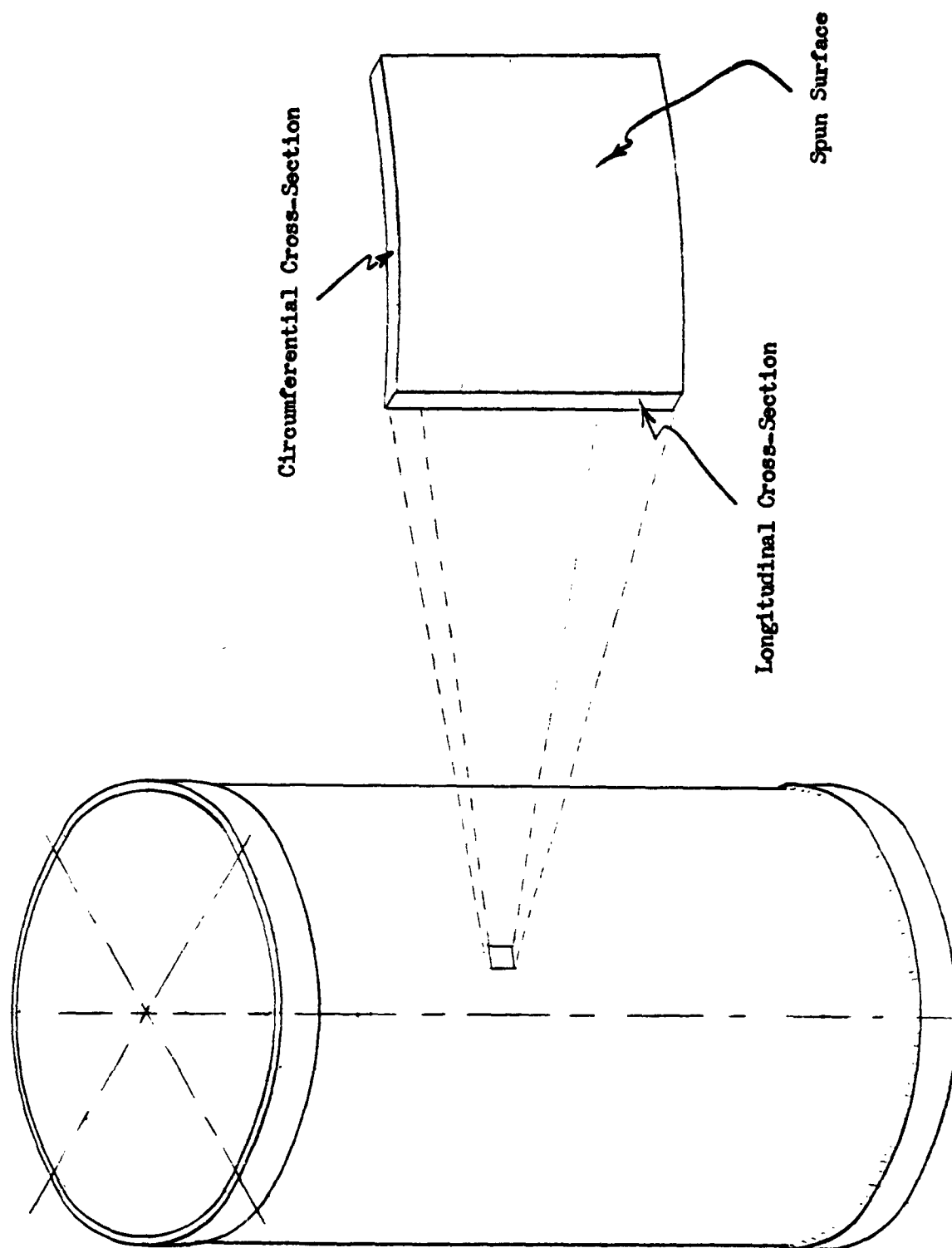
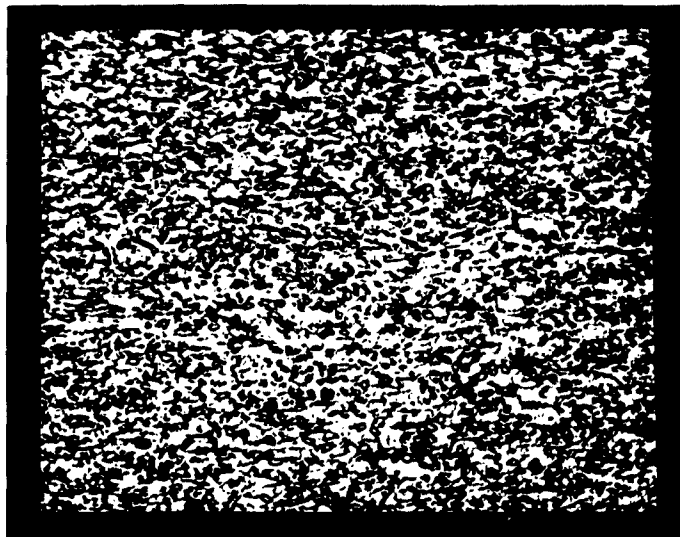


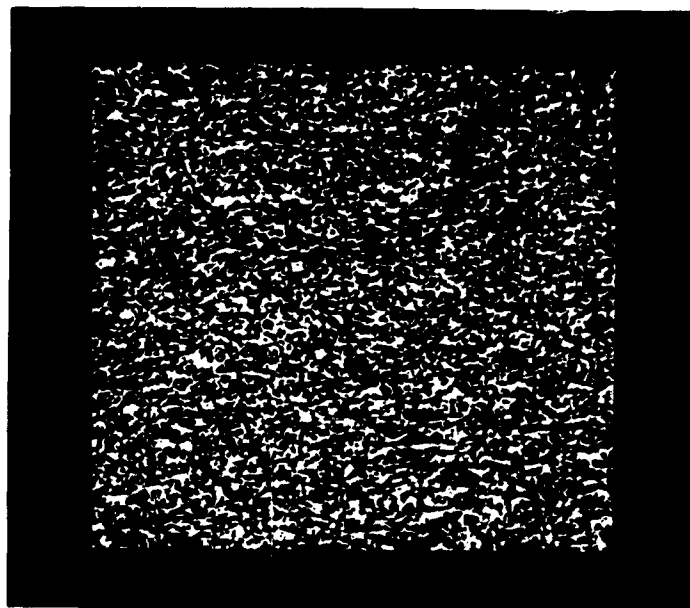
Figure 2 - Pictorial Representation of Directions Used for As Received Microstructures.



Roller Tool Marks

Figure 3

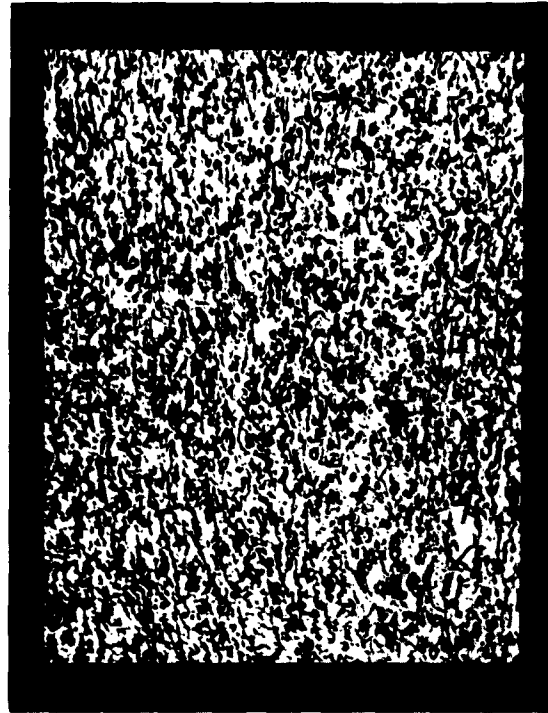
As Received Hydrospun MX-2 Microstructure of
the Vessel's Spun Surface. (Magnification 750 X)



Roller Tool Marks

Figure 4

As Received Hydrospun MX-2 Microstructure taken from
a Circumferential Cross-Section. (Magnification 750 X)



(Roller tool marks are directed into the paper)

Figure 5

As Received Hydrospon MX-2 Microstructure taken from
a Longitudinal Cross-Section. (Magnification 750 X)

Photomicrographs were also made of the heat treated conditions. Figure 6 shows the as quenched condition and Figure 7 shows the hardened and as tempered condition of the hydrospun surface.

The as quenched sample was used for a decarburization study. Hardnesses were taken across the entire width of the specimen. Figure 8 shows the hardness traverse across the thickness. It was found that the outside surface was decarburized $.007\frac{1}{2}$ in. and the inside surface .010 in.

The standard unnotched flat tensiles were heat treated along with the center notched specimens. Table II presents these results and also shows a higher tensile and yield strength for specimens taken from the longitudinal direction.

Table III compares the notch toughness and directionality effects of the welded center notched samples with that for the parent material. In this case, the circumferential direction indicated greater notch toughness. The circumferential center notched samples had the center notch coinciding with the weld. As seen from the table, the parent hydrospun material showed better properties.

D. Deep drawing of Rocoloy 270 and other experimental steels of this program into 10 in. hemispherical cups has been completed. These cups are intended for use in the evaluation of the biaxial stress-strain capabilities of various missile steels.



Figure 6 - Microstructure of Hydrospun MX-2. Annealed at 1250 F for 30 Min., Air Cooled, Austenitized at 1700 F for 30 Min., and Oil Quenched. (Mag. 500 X)

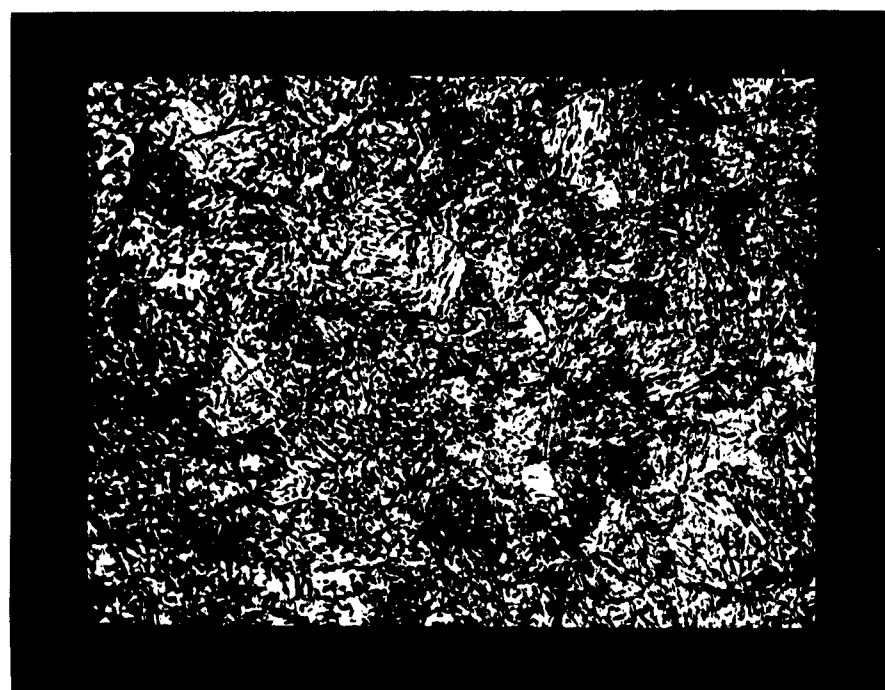


Figure 7 - Microstructure of Hydrospun MX-2. Annealed at 1250 F for 30 Min., Air Cooled, Austenitized at 1700 F for 30 Min., Oil Quenched, Tempered at 550 F for 2 + 1 hrs. and Air Cooled. (Magnification 500 X).

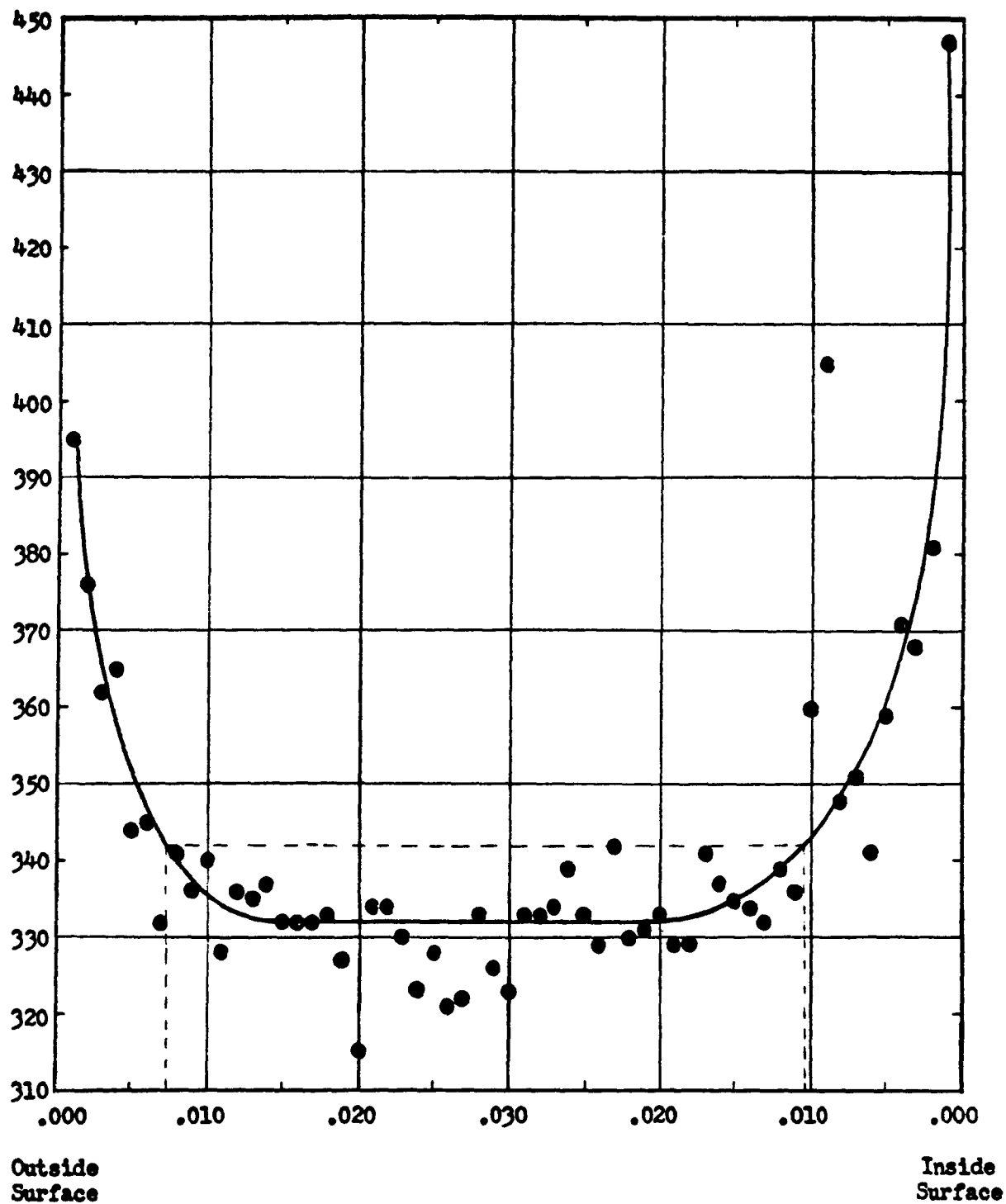


Figure 8

Microhardness Traverse Plot for Estimating
Decarburization on Heat Treated ML-2 Hydrospun Vessel.

TABLE II

Uniaxial Unnotched Tensile Results^(a)

Specimen Direction (b),(c)	Average Yield Strength ksi	Average Tensile Strength ksi	Average Fracture Strength ksi	Average Reduction in Area Per Cent	Average Elongation in 1" Per Cent	Hardness R _C
C	219	268	333	28.9	7.0	52.0
L	235	279	348	31.1	7.0	52.0

(a) Annealed at 1250 F for 30 min., air cooled, austenitized at 1700 F for 30 min., oil quenched, tempered at 550 F for 2 + 1 hr.

(b) C = Circumferential direction (parallel to roller tool marks).
L = Longitudinal direction (transverse to roller tool marks).

(c) Test section size = .500" x .060".

TABLE III

Results of Notch Tests on Heat Treated^(a) Hydrospon MX-2-47

	<u>Specimen No.(b)</u>	<u>σ_{net} ksi</u>	<u>G_c ipsi</u>	<u>Average σ_{net} ksi</u>	<u>Average G_c ipsi</u>	<u>Hardness RC</u>
<u>Longitudinal Direction</u>						
Weld Specimens	9-1	202	909	210	1010	52.0
	9-2	218	1110			52.0
Parent Material	9-3	186	812	186	815	52.0
	9-4	185	818			52.0
<u>Circumferential Direction</u>						
Weld Specimens	8-1	202	977	196	919	52.0
	8-2	190	860			52.0
Parent Material	8-3	208	1020	220	1080	52.0
	8-4	232	1140			52.0

(a) Annealed at 1250 F for 30 min., air cooled, austenitized at 1700 F for 30 min., oil quenched, tempered at 550 F for 2 + 1 hr.

(b) Gross section area = 3.000" x 0.060"
Notch length \approx .3 to .4 of the width of the specimen.

E. Evaluation studies of the effect of ultrasonic vibrations on the solidification of weldments have been continued. The use of this technique in order to produce very fine microstructure in welds is clearly demonstrated in Figures 9 through 11.

F. Weld filler wire development studies have been concluded.

G. Work on fabrication and testing of scale model rocket motor chambers made from suitable steels is continuing. However, no results can be reported for the present period.

H. Stress corrosion evaluation studies on MX-2 and Roccoloy 270 are continuing and no failure of any specimens has occurred since the last report on this subject.

The specimens to be used for the study of the effect of surface decarburization on various steel properties, are presently being heat treated. The controlled production of the required depths of decarburization has been a difficult task. However, this has been achieved with considerable success by careful manipulation of the moisture content of the hydrogen gas used.



No Ultrasonic Excitation



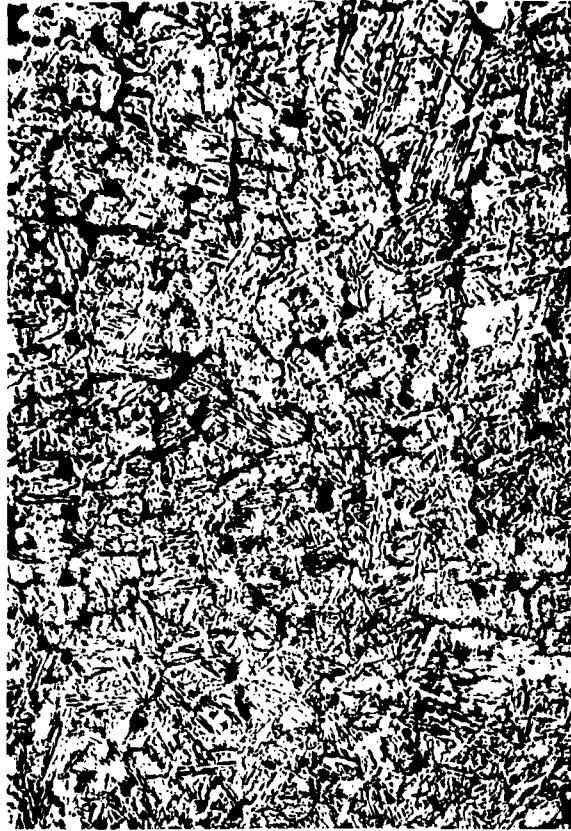
Ultrasonic Excitation

Figure 9

Photomicrographs showing the refinement produced by ultrasonic excitation.
95% Picral 5% HCl Etch X100 Welded and Stress-Relieved Structure.



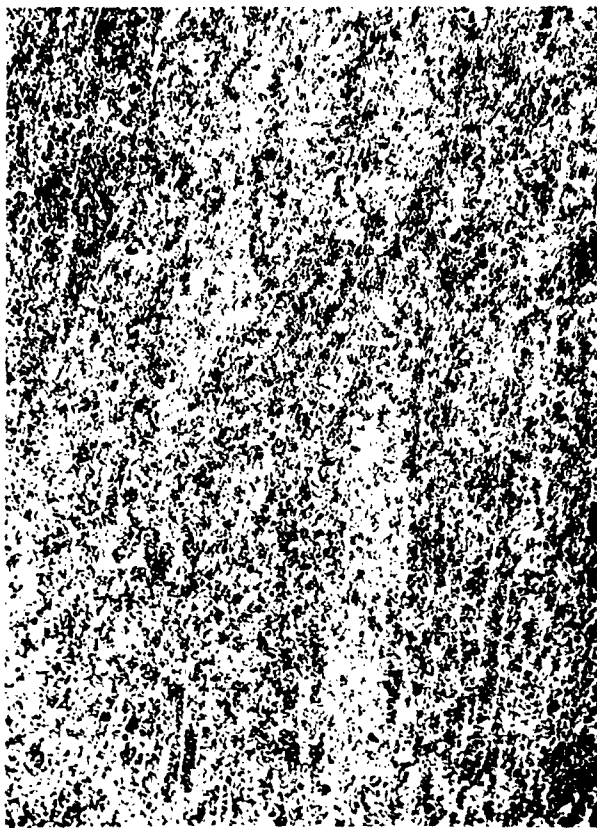
No Ultrasonic Excitation



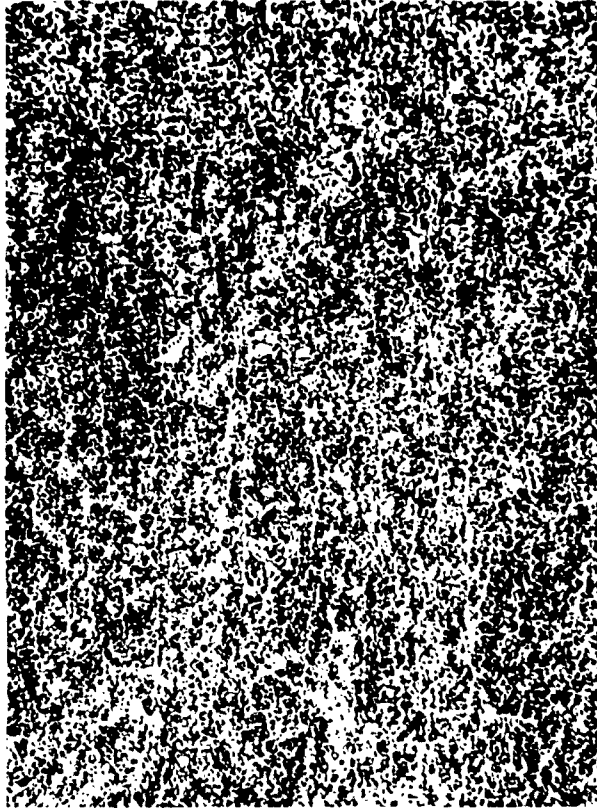
Ultrasonic Excitation

Figure 10

Photomicrographs showing the refinement produced by ultrasonic excitation.
95% Picral 5% HCl Etch X250 Welded and Stress-Relieved Structure.



No Ultrasonic Excitation



Ultrasonic Excitation

Figure 11

Photomicrographs showing the refinement produced by ultrasonic excitation.
9% Picral 5% HCl Etch X100 Austenitized, Oil Quenched and Tempered Weld Structure.

Work schedule during the month of August will include:

Further investigation of the effect of decarburization on the various physical and mechanical properties of missile steels and scale model motor cases.


Study of the effect of various additives to india ink or other suitable marking fluid, on the G_c and K_c value estimations.

Respectfully submitted,



G. K. Bhat
Project Leader

Approved:



H. L. Anthony III
Director of Research

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